

WHAT IS CLAIMED IS:

1. A system for computing a network code, comprising:  
computing flows between at least one sender and two or more receivers;  
5 and  
computing network code coefficients restricted to the computed flows.
2. The system of claim 1 wherein the network code coefficients  
include:  
10 encoding vectors for each interior network node, including a sender; and  
decoding matrices for each receiver.
3. The system of claim 2 wherein the elements of the encoding  
vectors and decoding matrices are elements of a finite field whose size does not  
15 depend on the rate of the computed flows.
4. A system for transmitting symbols from at least one sender to two  
or more receivers via a plurality of interior network nodes, comprising:  
restricting the symbols to flows between the at least one sender and the  
20 two or more receivers;  
encoding at each interior network node the symbols entering the node into  
symbols exiting the node; and  
decoding at each receiver the symbols entering the receiver.
- 25 5. The system of claim 4 wherein the encoding and decoding are  
linear operations.
6. The system of claim 5 wherein the linear operations are over a  
finite field whose size is independent of the rate of the computed flows.

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7. A system for computing a network code, comprising:  
computing linear combination coefficients for each of at least one interior  
network node of a network, said nodes including a sender;  
computing representation vectors for symbols exiting each interior network  
5 node from representation vectors for symbols entering each node and the linear  
combination coefficients; and  
computing decoding matrices for each of at least one receiver of the  
network from the representation vectors for the symbols entering each receiver.

10 8. The system of claim 7 further comprising setting encoding vectors  
for each interior node, including the sender, to the linear combination coefficients.

9. The system of claim 7 wherein computing the linear combination  
coefficients further includes ensuring that the representation vectors for the  
15 symbols transmitted across edges on a cut between the sender and each  
receiver are full rank.

10. A computer-implemented process for computing efficient network  
codes for a multicast network, comprising using a computing device to:  
20 receive known parameters defining a multicast network, which includes a  
plurality of internal network nodes, including at least one sender, and two or more  
receivers;  
compute flows between the sender and the two or more receivers using  
the known parameters; and  
25 compute encoding vectors for each internal network node, including the at  
least one sender, wherein encoding vector coefficients are restricted to the  
computed flows; and  
compute decoding matrices for each receiver.

11. The computer-implemented process of claim 10 wherein computing efficient network codes for a multicast network includes an initialization stage comprising:

reducing the multicast network to a network with edges between internal  
5 nodes having unit capacities by replacing each edge having a capacity  $c$  with  $c$  edges having unit capacity.

12. The computer-implemented process of claim 11, wherein the initialization stage further comprises:

10 a determination of whether each edge having unit capacity is within the computed flows; and

ordering any edges within the computed flows topologically from the sender to the two or more receivers.

15 13. The computer-implemented process of claim 12 wherein the topologically ordered edges are used for computing the encoding vectors.

14. The computer-implemented process of claim 12 wherein the topologically ordered edges are used for computing the decoding matrices for  
20 each receiver.

15. The computer-implemented process of claim 10 wherein the network parameters include:

a network layout;  
25 a flow capacity of each internal node in the network, including flow capacities of the at least one sender and the two or more receivers.

16. A computer-implemented process for computing a network code for a network including at least one sender, a plurality of internal nodes and at least  
30 one receiver, comprising using a computing device to:

compute linear combination coefficients for each interior network node and the at least one sender;

compute representation vectors for symbols exiting each interior network node from representation vectors for symbols entering each interior network node and the computed linear combination coefficients; and

compute decoding matrices for each receiver from the representation vectors for the symbols entering each receiver.

17. The computer-implemented process of claim 16 further comprising designating the linear combination coefficients as encoding vectors for each interior node and the at least one sender.

18. The computer-implemented process of claim 16 wherein computing the linear combination coefficients further includes ensuring that the representation vectors for symbols transmitted across edges on a cut between the sender and each receiver are full rank.

19. A method for constructing multicast network codes, comprising:  
inputting a network layout defined by:  
two or more receivers,  
a plurality of internal network nodes with at least one edge between each node, said nodes including a sender, and  
a flow capacity of each edge;  
computing flows from the network layout between the sender and the two or more receivers;  
computing network codes for each internal network node, including the sender, from the computed flows, said network codes comprising encoding vectors for encoding one or more symbols for multicast transmission from the sender through the network to the two or more receivers; and  
computing decoding matrices for each receiver for decoding each encoded symbol multicast to each receiver.

20. The method of claim 19 wherein computing flows from the network layout between the sender and the two or more receivers includes an initialization stage comprising:

- 5       reducing the network layout by replacing each edge having a capacity  $c$  with  $c$  edges having unit capacity; and
- determining whether each edge having unit capacity is within the computed flows.

21. The method of claim 20 wherein the initialization stage further  
10   comprises ordering any edges determined to be within the computed flows topologically from the sender to the two or more receivers.

22. The method of claim 21 wherein the topologically ordered edges are used for computing the decoding matrices for each receiver for decoding  
15   each encoded symbol multicast to each receiver.